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Analysis of LCTA Methods for Inventory and Monitoring Birds and Small Mammals on Army Lands in the Southwestern United States

by
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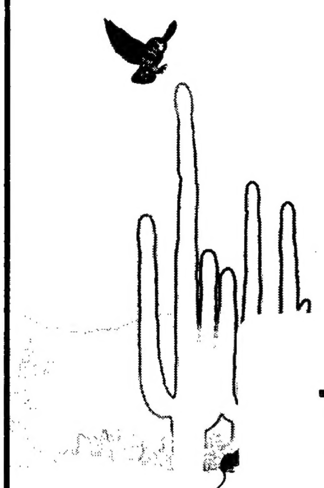

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The U.S. Army's Land Condition Trend Analysis (LCTA) Program was established to inventory and monitor ecological systems on Army lands using standard methods. Information obtained using LCTA can help installation resource managers meet multiple-use demands. Although LCTA data have been collected on various installations and analysis is underway, few studies have evaluated whether LCTA methods are effective in detecting ecological changes. One approach to this evaluation is through power analysis.

This study uses power analysis to evaluate bird and small mammal inventory and monitoring protocols in Army lands in the southwestern United States. Specifically, the study addresses field sampling techniques, sampling design, and analytical approaches and uses four commonly used diversity indices for detecting community differences.

The four diversity indices examined in this study yielded low power in detecting community differences and are consequently poor measures for detecting community change. Statistical power varied between field collection methods. Power also varied between installations, which suggests that standard nation-wide sampling protocols will vary in efficiency and effectiveness among locations.

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13. ABSTRACT (Maximum 200 words)

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This study uses power analysis to evaluate bird and small mammal inventory and monitoring protocols in Army lands in the southwestern United States.

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Foreword

This study was conducted for the Assistant Chief of Staff for Installation Management under Project 4A162720A896, "Environmental Quality Technology"; Work Unit TY6, "Inventory and Monitoring of Rare, Threatened, and Endangered Species on Military Lands." The technical monitor was Phil Pierce, DAIM-ED-R.

The work was performed by the Natural Resource Assessment and Management Division (LL-N) of the Land Management Laboratory (LL), U.S. Army Construction Engineering Research Laboratories (USACERL). Stephen Demarais and Richard Hansen are affiliated with the Department of Range and Wildlife Management, Texas Tech University. The USACERL principal investigator was Dr. Clifford G. Rice. Dr. David J. Tazik is Acting Chief, CECER-LL-N; Dr. William D. Severinghaus is Operations Chief, CECER-LL. The USACERL technical editor was Gloria J. Wienke, Technical Resources.

Dr. Michael J. O'Connor is Director of USACERL.

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1 Introduction

Background

Monitoring ecological systems is necessary to measure and assess change. The U.S. Army's Land Condition Trend Analysis (LCTA) program was established to inventory and monitor ecological systems on Army lands using a standardized methodology (Diersing, Shaw, and Tazik 1992, Tazik et al. 1992). Information obtained using LCTA is designed to assist installation resource managers in meeting multiple-use demands (Diersing, Shaw, and Tazik 1992, Tazik et al. 1992).

The ability to detect changes in ecological systems depends on monitoring methods, appropriate experimental design, and analytical approaches. LCTA data have been collected on various installations, and analysis and interpretation is underway (Price et al. 1995). Unfortunately, few studies have evaluated whether LCTA methods are effective in detecting ecological change (Rice, Demarais, and Hansen in press). A useful approach in evaluating the suitability of LCTA methods for assessing ecological change is through power analysis.

Statistical power is the probability of detecting a specified level of difference between variables using statistical analysis (Cohen 1988; Lipsey 1990). Lack of power resulting from inefficient monitoring methods and analysis can result in the failure to identify ecological change when it occurs (Type II Error). This could result in recommendations that are inappropriate for meeting natural resource management goals on Army lands. Therefore, statistical power analysis assesses the monitoring program's suitability for making land management recommendations.

Objectives

The objectives of this study were to evaluate, using power analysis, bird and small mammal inventory and monitoring protocols on Army lands in the southwestern United States. Specifically, the study addressed three aspects of bird and small mammal community survey design: field sampling techniques; sampling design; and analytical approaches.

Approach

Statistical power analysis (Cohen 1988; Lipsey 1990) was used to evaluate various field survey methods and analytical approaches of the LCTA program. Monitoring methods are designed to detect ecological change over time. In this study, differences in vertebrate community composition between two habitats served as a surrogate for differences in a given habitat over time. Power analysis was used to contrast composition (number of individuals of each species) between respective avian and small mammal communities occurring in two distinct habitats at each of three Army installations. Also, four commonly used diversity indices were evaluated for their utility in measuring ecological differences.

2 LCTA Methods

LCTA plot inventory field methods were presented by Tazik et al. (1992) from which the following procedures are summarized. LCTA surveys are conducted on permanent plots at each Army installation. Location of plots are chosen using an automated site selection process to ensure objectivity, randomness, and representation. Plots are allocated proportionally to land cover types on each installation as delineated by SPOT (Systeme Probatoire por l'Observation de la Terre) satellite imagery, soil surveys, and the GRASS (Geographic Resources Analysis Support System) geographic information system. The number of plots depends on the size of the installation and the variation in land cover and soil types. Approximately one plot per 200 ha, with a maximum of 200 plots on large installations, is recommended. The standard LCTA plot is 100 x 6 m. A 100-m transect is established along the longitudinal axis of the plot, in which various biotic and abiotic factors are measured. Data collection occurs in three phases, initial inventory, short-term monitoring, and long-term monitoring. After the initial inventory phase, plots are monitored on a regular basis (usually annually) for changes in land use, such as surface disturbance, ground cover, canopy cover, and floral and faunal composition.

Avian Surveys

A modified point-count transect survey is used to census avifauna. At each survey plot, an observer takes 6 minutes to walk the 100-m transect and record all birds detected by sight or sound within 100 m of the transect line. The observer remains stationary at the end of the transect for 8 minutes and records all birds detected. The observer then takes 6 minutes to return to the starting point, again recording all birds detected within 100 m of the transect. At each plot, avian surveys are conducted twice per survey period; once in the first four hours of daylight and once in the last four hours of daylight. Surveys are conducted during the seasonal peak in avian activity at each installation.

Small Mammal Surveys

For each plot, a trap array is constructed of 40 Museum Special traps and 10 rat snap traps. Museum Special traps are placed 7.5 m apart along two lines 15 m from, and parallel to the 100 m LCTA transect. The rat traps are positioned 1 to 2 m to the interior of the Museum Special traps; the first rat trap is placed coincident to the third Museum Special trap and thereafter spaced 30 m apart. Traps are baited with a peanut butter-rolled oats mixture and are set for two consecutive nights to obtain a total of 100 trap-nights per plot. All captures are removed from the survey plots for later identification. Trapping is conducted during the seasonal peak in small mammal activity at each installation.

3 Study Area and Methods

Field trials were conducted at three installations, Camp Florence, AZ; Fort Hood, TX; and Fort Bliss, NM-TX (Figure 1*). At each installation, two habitats were selected for conducting avian and small mammal surveys. Habitats were chosen on the basis of observed differences in plant species associations.

Habitats selected at Camp Florence were creosote and cactus. Creosote bush (*Larrea tridentata*) was the dominant species in the creosote habitat, followed by cholla (*Opuntia* spp.) and velvet mesquite (*Prosopis juliflora*). The cactus habitat was composed of a combination of cactus, trees, and shrubs. Saguaro (*Carnegiea gigantea*), yellow palo-verde (*Parkinsonia microphyllum*), desert ironwood (*Olneya tesota*), and chollas were the primary plant species of this habitat.

At Fort Hood, the two habitats were forest and savannah. Forest habitat was composed primarily of live oak (*Quercus fusiformis*) and cedar (*Juniperus ashei*). Understory vegetation included redbud (*Cercis canadensis*), possum-haw (*Ilex decidua*), elbow-bush (*Forestiera pubescens*), and bunch grasses. Savannah habitat contained scattered cedars and several grass species including little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum avenaceum*), and sideoats grama (*Bouteloua curtipendula*).

Upland and arroyo habitats were selected at Fort Bliss. White-thorn acacia (*Acacia constricta*) and ephedra (*Ephedra* spp.) were the primary shrub species in the upland habitat. Grasses included sideoats grama, black grama (*Bouteloua eriopoda*), muhlys (*Muhlenbergia* spp.), and three-awns (*Aristida* spp.). The arroyo habitat was associated with xeroriparian zones scattered around the study area. Shrubs included littleleaf sumac (*Rhus microphylla*), tarbush (*Flourencia cernua*), and fourwing saltbush (*Atriplex canescens*). Grasses in arroyo habitats included tobosa (*Hilaria mutica*), alkali sacaton (*Sporobolus airoides*), saltgrass (*Distichlis spicata*), and blue grama (*Bouteloua gracilis*).

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* Figures and tables are presented at the end of each chapter.

Avian Surveys

For surveys at Camp Florence and Fort Hood, four sites were located within each of the two habitats where LCTA surveys (walk-in, point count, and walk-out) were carried out (Figure 2). Seven survey combinations derived from the original LCTA-type survey method were examined. These were: (1) walk-in portion of survey, (2) walk-out portion of survey, (3) point count survey, (4) walk-in and walk-out portion of survey, (5) walk-in portion and point count survey, (6) walk-out portion of survey and point count survey, and (7) all three survey methods combined (LCTA standard survey). Surveys were conducted on 8 days at each site. Avian surveys were conducted at Camp Florence between 3 and 19 March 1993 and at Fort Hood between 17 June and 12 July 1993.

At Fort Bliss, each of the two habitats had six replicate sites. Avian survey methods at each site included eight point count surveys and one LCTA-type survey and were arranged along the arroyo. Surveys were conducted for 4 days on each site from 5 May to 8 June 1993 and 3 to 23 May 1994.

Small Mammal Surveys

For surveys at Camp Florence and Fort Hood, the four sites selected for avian surveys were also used for small mammal surveys. Surveys consisted of three different trapping arrays located on each site (Figure 2). These included the Museum Special and rat snap trap array (standard LCTA trap array), Sherman live trap and rat snap trap array, and Sherman live trap and pitfall array (Figure 3). Pitfall drift fences were constructed from roof flashing and were approximately 41 cm high and 10 m long; buckets were 22 cm in diameter and 31 cm deep. Trapping arrays were monitored for 8 nights. Surveys were conducted at Camp Florence between 8 September and 15 October 1993 and at Fort Hood between 26 October and 3 December 1993.

At Fort Bliss, each of the two habitats had five replicate sites. Trapping was conducted with a 90-trap array using Sherman live traps set for 4 consecutive nights. Traps were set 20 m apart along three 300-m rows; spacing between each row was 10 m. Trapping was conducted between 25 April and 20 May 1993.

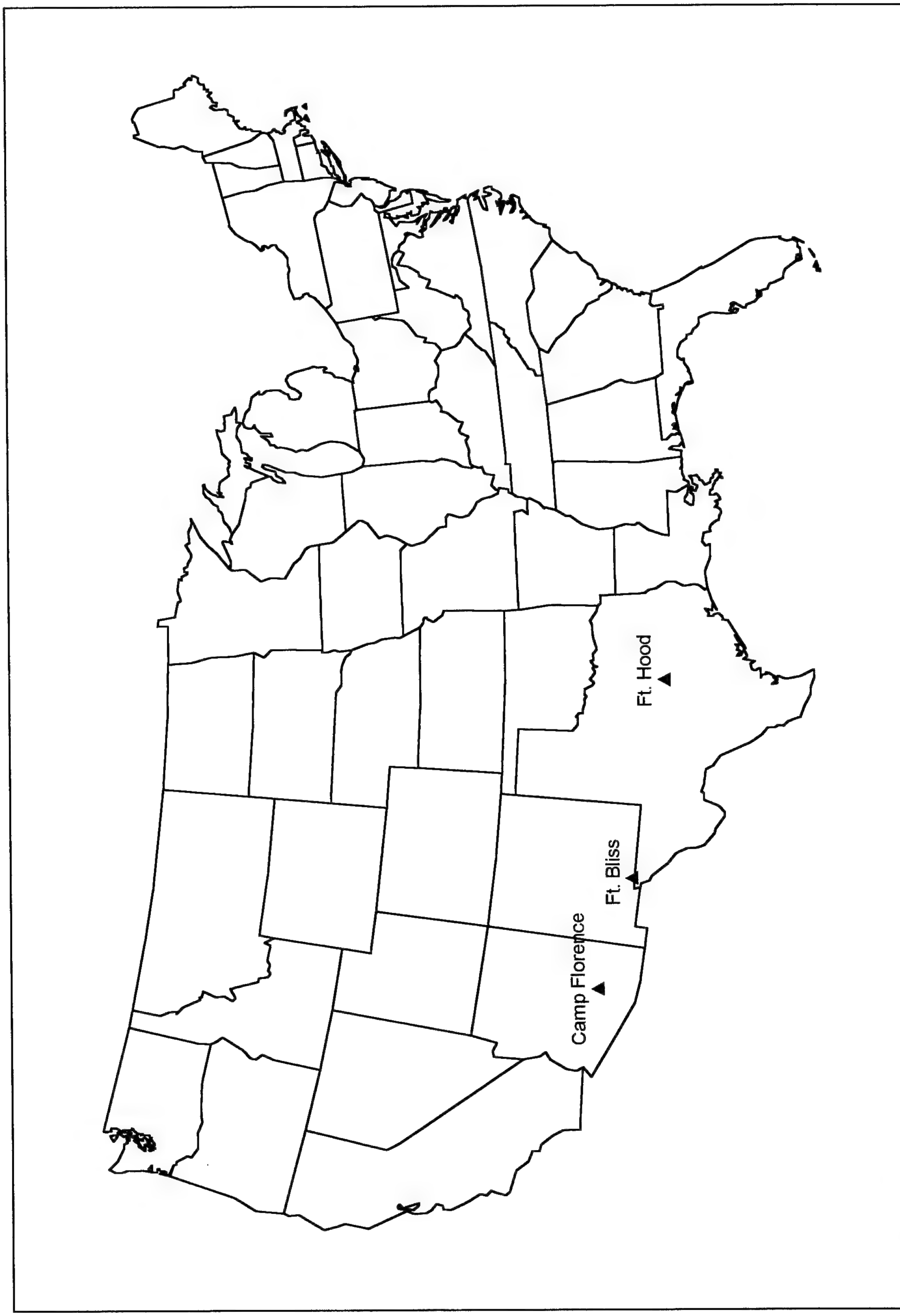


Figure 1. Locations of study sites.

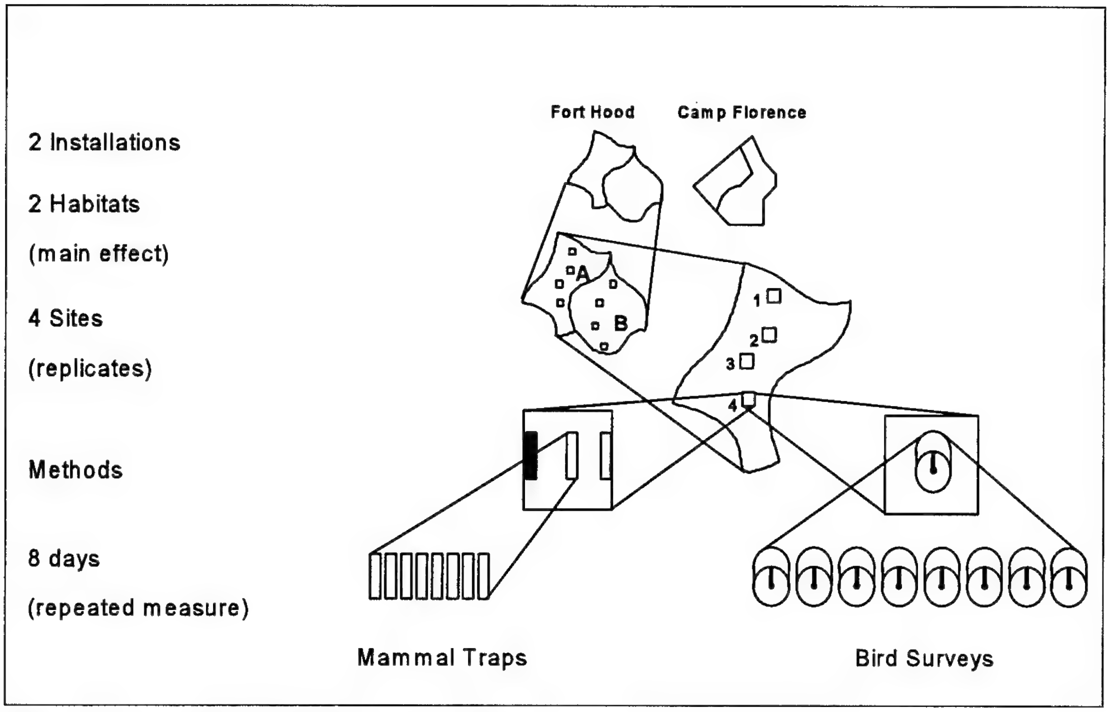


Figure 2. Schematic layout of field sampling.

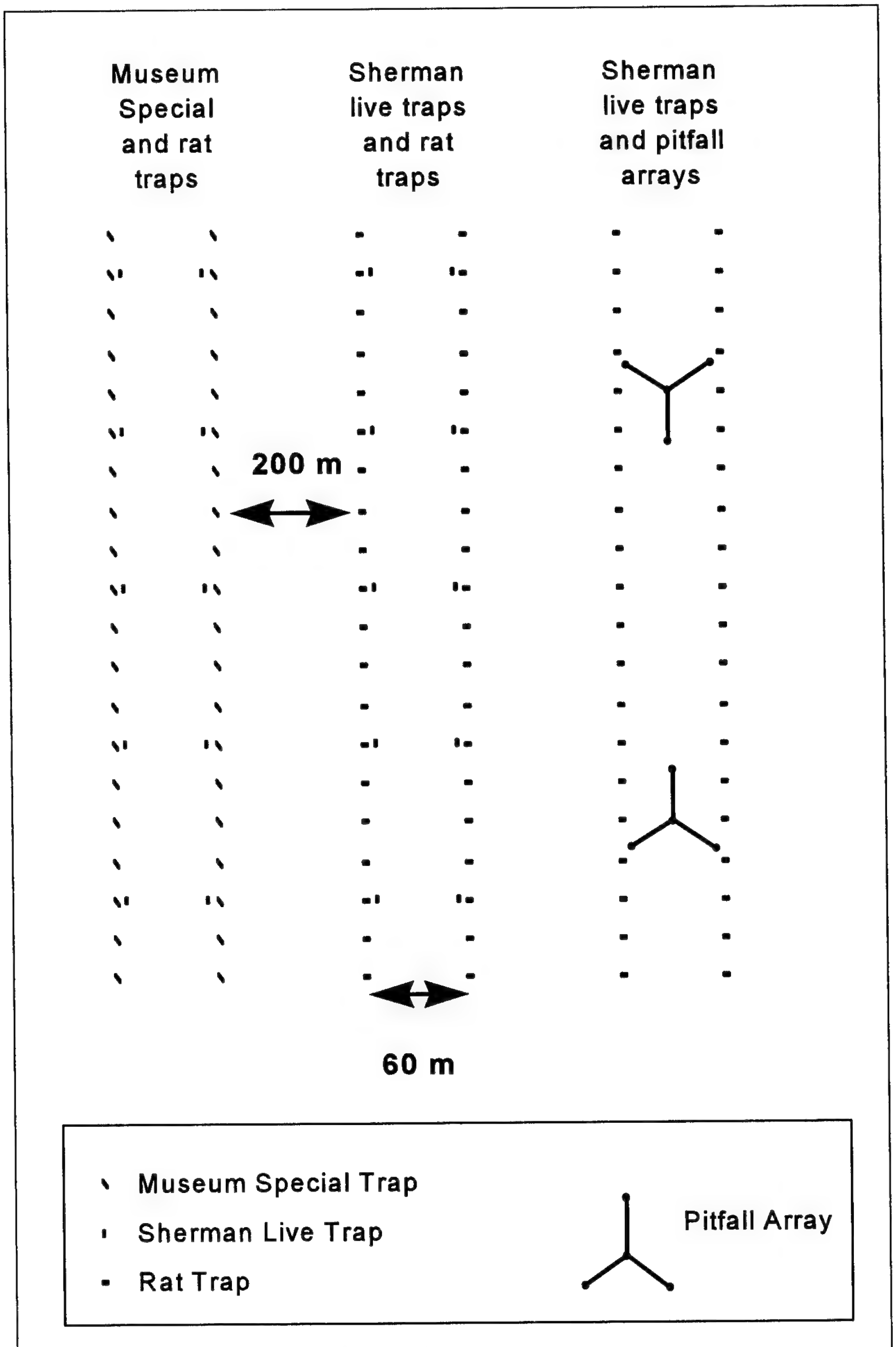


Figure 3. Configuration of small mammal trapping arrays at Camp Florence and Fort Hood.

4 Analysis

LCTA methods do not stipulate specific analytical approaches (Tazik et al. 1992). To avoid biases related to survey methods, and because the primary objective was to detect differences between communities rather than estimating their exact composition, the avian and small mammal communities (actual numbers observed, detected, or captured) were analyzed. Data collected from these surveys were used in two ways: (1) as a direct measure of community composition and (2) for calculating diversity indices. Data from each installation were analyzed separately for two reasons. First, the primary objective was to determine if community differences could be detected between habitats within installations and not among installations and second, the effect sizes, which are determined by the differences between communities, were not standardized among installations.

A repeated measures analysis of variance (ANOVA) design was used in the analysis. The multivariate approach to repeated measures ANOVA is severely affected by missing values (Dunn and Clark 1974), and it was not used for this reason. Missing values were from missed surveys (due to poor weather conditions, equipment failure, etc.) and results for which it was impossible to calculate diversity index values (see Chapter 6, Discussion).

The alternative, a nested univariate approach to ANOVA with repeated measures (Norusis 1993) was used. In this design, the response variable was the number of individuals of each species recorded, sites were the experimental unit, repeated measures were days of surveying, and in the case of combined bird survey assessments, survey method also was a repeated measure.

In assessing community differences, two types of effect were considered; the habitat main effect, and the species-habitat interaction affect. The first assesses the degree of change in number of individuals for all species together, whereas the second assesses the relative number of individuals for each species between the communities (Figure 4).

For the habitat main effect, the test statistic was the ratio of the mean square for habitat to the mean square for site within habitat. The statistical test of interest for the community composition analysis was the ratio of the mean square for the

habitat-species interaction and the mean square for species by site within habitat. A significant interaction indicated that the number of individuals of each species in one habitat was different from the number of individuals of each species in the other habitat (i.e., vertebrate communities were different, Figure 4; Rice, Demarais, and Hansen in press). Power values were generated using the power option of SPSS (Norusis 1993).

Typically, ANOVA is used to evaluate the probability (*P*) that sample means are different. In this study, the assumption was that there were differences in faunal communities between differing habitats; interest was in the probability of detecting that difference, or statistical power ($1 - \beta$). Power is a function of the significance level chosen for the statistical test (α), sample size (n), variability in the data, and the effect size (ES). Since the power of statistical tests using each survey method was of interest, power was estimated for each survey method. Including survey methods as a treatment effect in the ANOVA models would have determined whether various survey methods produced statistically significant results, but would not have provided information needed to assess which field methods yielded the most powerful tests.

There is no consensus on what is considered adequate power, but 0.80 ($\beta = 0.20$) is commonly used in research (Cohen 1988; Lipsey 1990). Determination of the necessary statistical power is a management decision, but for discussion in this study, a power level of 0.80 was considered adequate. For all analyses, $\alpha = 0.05$ was used.

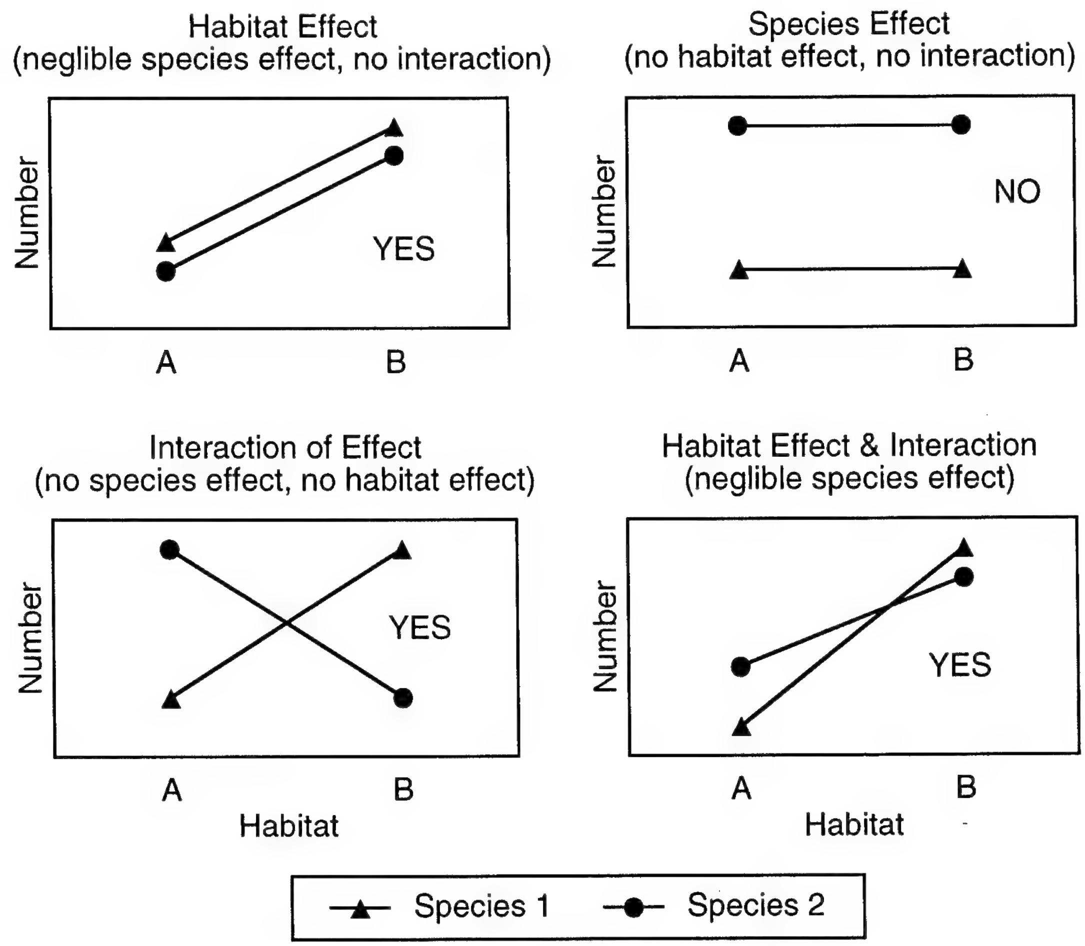
In power analysis, the effect of sampling intensity on power usually can be estimated with power tables, power curves, or formulas after a test is completed (Cohen 1988; Lipsey 1990). In this study, sampling intensity for each of the two habitats was determined by the number of survey sites and number of survey days. Consequently, it could not be determined if the estimated change in power due to a different sampling intensity was associated with a comparable change in the number of sites surveyed or the number of days sampled. An alternate approach was used to calculate power using subsamples of the complete data set that represented differing numbers of sites and survey days. Because there were numerous possible permutations for most of these subsamples, power was calculated for five randomly selected permutations for each combination of sites and days. Power for that particular combination of sites and days was estimated as the mean of the five subsamples; generated values were graphed and compared visually (see Chapter 5, Results). For avian surveys, days were selected randomly because they were assumed to be unbiased by chronology. Small mammal data were treated as a chronological string (e.g., five sample days were always one through five) due to the

effects of sampling duration on mammal trapping (Renzulli, Flowers, and Tamarin 1980; Bury and Corn 1987).

Because power is closely related to sample size, contour graphs illustrating power as a function of both number of sites and number of days surveyed can be expected to have a concave shape, as a plot of n does (where n = days × sites). Greater effect on power from either sites or days is evidence by differences from the basic pattern (Figure 5).

Diversity was measured for avian and small mammal communities for each of the two habitat types on the three installations. Four common diversity indices were calculated (Table 1): species richness (S) (McIntosh 1967), reciprocal of Simpson's dominance index (d_s) (Simpson 1949), Shannon's index (H') (Shannon and Weaver 1949), and Fisher's α (Fisher, Corbet, and Williams 1943). Power analysis for diversity indices was based on the habitat main effect on bird or small mammal species composition.

Four similarity indices were used (Table 2) to evaluate community composition and structure between the two habitats at each of the three installations and relate these findings to effect size and diversity index values. The percent similarity index (PS) (Pielou 1975) evaluated the similarity in the number of species in both habitats (independent of co-occurrence). The Jaccard index (C_j) (Jaccard 1908) was used to determine the similarity of species co-occurrence between both habitats. Two quantitative indices (includes both presence and abundance data) were used: the Sorenson quantitative index (C_N) (Bray and Curtis 1957) and the Morisita-Horn index (C_{MH}) (Horn 1966). The Morisita-Horn index was selected because it is less affected by sample size and species diversity than other quantitative similarity indices (Wolda 1981).



YES indicates effects that a monitoring program should detect.

Figure 4. Schematic representation of community comparisons by species composition.

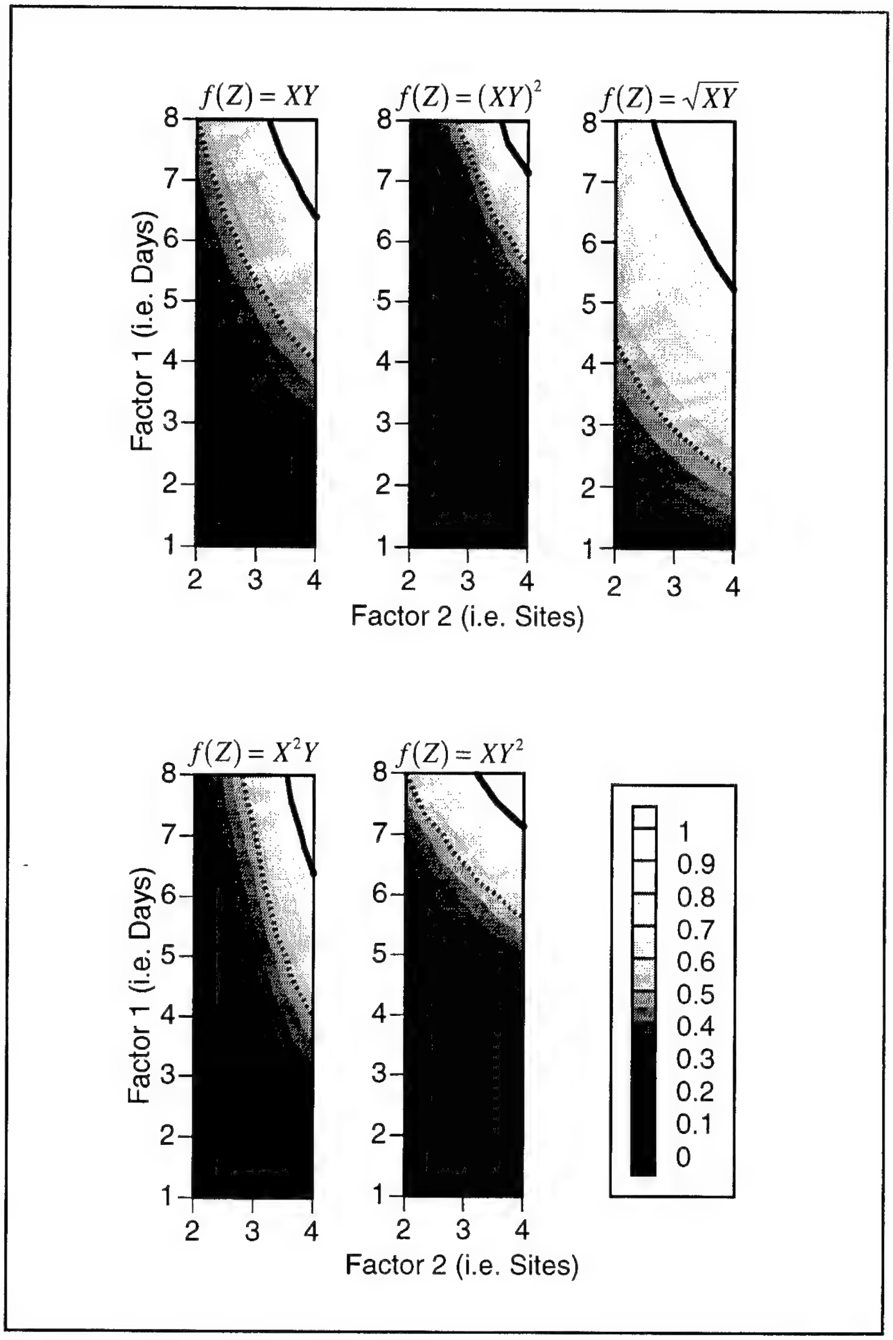


Figure 5. Hypothetical contour graphs of power.

Table 1. Diversity indices used for comparisions in LCTA methods evaluation.

Index	Symbol	Formula	Reference
Species Richness	S	S	McIntosh 1967
Reciprocal of Simpson's Dominance	d_s	$d_s = \frac{N(N-1)}{\sum n_i(n_i-1)}$	Simpson 1949
Shannon's	H'	$H' = \sum \frac{n_i}{N} \log \frac{n_i}{N}$	Shannon and Weaver 1949
Fisher's α	α	simultaneously $S = -\alpha \log_e(1-x)$ and $N = \frac{\alpha x}{1-x}$ for α and x	Fisher et al. 1943

N = total number of individuals in the sample.
S = number of species in the sample.
n_i = number of individuals in the ith sample

Table 2. Similarity indices used for comparisons in LCTA methods evaluation.

Index	Symbol	Formula	Reference
Percent Similarity	*PS*	$PS = 200\sum_{i=1}^{S} \min(P_{iX}, P_{iY})$	Pielou 1975
Jaccard	C_j	$C_j = \dfrac{j}{a+b+j}$	Jaccard 1908
Sorenson quantitative	C_N	$C_j = \dfrac{2jn}{aN+bN}$	Bray and Curtis 1957
Morista-Horn	C_{MH}	$C_{MH} = \dfrac{2\sum[(an_i)(bn_i)]}{(da+db)[(aN)(bN)]}$ where: $da = \dfrac{\sum an_i^2}{aN^2}$ and $db = \dfrac{\sum bn_i^2}{bN^2}$	Horn 1966

P_{iX} and P_{iY} are quantities of species *i* in habitats X and Y as proportions of the quantities of all *S* species in the two habitats combined.
j = number of species common to both habitats A and B.
a = number of species in habitat A.
b = number of species in habitat B.
jn = sum of the lower of the two abundances recorded for species found in both habitats.
aN = number of individuals in habitat A.
bN = number of individuals in habitat B.
an_i = number of individuals of the *i*th species in habitat A.
bn_i = number of individuals of the ith species in habitat B.

5 Results

Avian Communities

Avian species found during the surveys are listed in Tables 3 through 5. Avian communities at Camp Florence and Fort Hood showed little difference in the number of species between habitats, as reflected by relatively high *PS* values (Table 6). High values for Jacard's index indicated that a large proportion of species co-occurred in both habitats at these two installations (Table 6). However, larger differences were observed between habitats at Fort Bliss. Substantially more bird species were found in the arroyo habitat (45 species) than were found in the upland habitat (21 species); only 18 species were found in both habitats (Table 5).

At Camp Florence and Fort Hood, high values of the Sorensen and Morisita-Horn indices (Table 6) suggest relative evenness in avian communities between the two habitats. Fort Bliss had lower values of both indices (Table 6). This suggested substantial difference in avian community structure (number of species and number of individuals of species) between the two habitats at Fort Bliss.

Habitat main effects yielded less power than species-habitat interactions for detecting community differences. Power values for the habitat main effect and species-habitat interaction, respectively, were 0.23 and 0.84 at Camp Florence, 0.11 and 0.85 at Fort Hood, and 0.53 and 0.88 at Fort Bliss.

At Camp Florence, the point count surveys yielded the lowest power of all survey methods (Figure 6). The walk-in survey yielded adequate power ($\geq$ 0.80) with four or more survey days. The walk-out survey yielded adequate power with three or more days, and consistently showed higher power than the walk-in survey. Combinations of survey methods also yielded high power at three or more survey days and had higher power levels than point surveys (Figure 6). Power contours, generated from all survey methods combined, indicated that power increased with an increase in the number of survey sites and survey days (Figure 7). At Camp Florence, sufficient power was obtained with two survey sites and seven survey days, three sites and three days, and four sites and three days (Figure 7). At Fort Hood, sufficient power was obtained with three survey sites and four days, and five survey sites and three days.

At Fort Hood, none of the avian survey methods or combinations yielded adequate power (Figure 8), and most of the survey methods or combinations did not yield increased power with increasing survey days. Only the point count and walk-in combination yielded power values slightly above 0.70, but only for survey days two through five and on the eighth survey day. Power values generated from the walk-in and walk-out combination actually declined with increasing survey days. Surface contours of statistical power, generated with all survey methods combined, indicated that with combinations of both survey sites and survey days, statistical power reached 0.50 but failed to attain adequate power (Figure 7). Additionally, there was no observable pattern in which power increased due to concomitant increases in the number of sites or survey days.

Power associated with avian surveys on Fort Bliss indicated that both the point count method and the combined methods (LCTA-type survey) had sufficient power (Figure 9). Both increased in power with increasing number of survey days. Power for point counts were above 0.80 with three survey days, and for all combinations of survey methods, sufficient power was reached on the second survey day (Figure 9). Surface contours of statistical power using both sites and days indicated that three sites and four survey days, and five sites and three days achieved adequate power (Figure 7).

Small Mammal Communities

Species found during small mammal surveys are listed in Tables 7 through 9. At Camp Florence, high percent similarity indicated that both habitats contained similar numbers of species and high Jaccard's index values indicated that a high proportion of the same species occurred in both habitats (Table 6). These results were similar to findings at Fort Bliss (Table 6). At Fort Hood, both these values were low (Table 6). This indicated that the number of species between habitats varied and that few species occurred in both habitats, respectively.

Both Sorenson and Morisita-Horn indices varied dramatically at each installation (Table 6). The small number of species found in both habitat types at each installation may have biased Sorenson index values. Values of the Morisita-Horn index suggested a lack of evenness between small mammal communities, particularly at Camp Florence and Fort Hood. Further examination of data collected at these two installations found one or two species numerically dominated in a particular habitat (Tables 7 and 8).

For small mammal data collected at Camp Florence and Fort Hood, power to detect habitat main effects was extremely low compared to species-habitat interactive effects. Power values for the habitat main effect and species-habitat interaction were 0.12 and 0.96 at Camp Florence, 0.07 and 0.83 at Fort Hood, and 0.85 and 0.99 at Fort Bliss, respectively.

At Camp Florence, power was consistently high (>0.95) for the Sherman/rat trap and Sherman/pitfall trap arrays (Figure 10). High power was obtained even with only one night of trapping using these methods. Although power was initially lower for the Museum Special/rat trap array, adequate power was obtained with only two nights trapping and achieved similar power values to the other methods on the fifth night (Figure 10). Power contours indicated that the Sherman/rat trap array achieved adequate power with two sites and two nights of trapping, and three sites and one night of trapping (Figure 11). For the Sherman/pitfall trap array, adequate power was obtained with three sites and two nights of trapping, or four sites and one night of trapping. The Museum Special/rat trap array had the lowest power of the three trap arrays, but adequate power was obtained with three sites and five trap nights, or four sites and two trap nights (Figure 11).

At Fort Hood, the Museum Special/rat trap array yielded low power (<0.20), even after eight nights of trapping (Figure 10). Sufficient power for the Sherman/rat trap array was attained on the fifth night of trapping. Power with the Sherman/pitfall array was highly variable. Power values increased to over 0.8 on the fifth trap night, then declined (Figure 10). Statistical power contours generated for the Sherman/rat trap array and the Sherman/pitfall trap array indicated that sufficient power was obtained with four sites and five nights trapping, but power contours appeared to be too variable to elucidate any trend associated with increasing sites or sampling nights (Figure 12). For the Museum Special/rat trap array, no combination of sites and days yielded power values above 0.5 (Figure 12).

At Fort Bliss, all combinations of sites and days obtained sufficient power (Figure 13). Sufficient power was obtained with only two survey sites and two nights of trapping using the 90-trap array of Sherman live traps.

Diversity Indices

Diversity indices were calculated for avian communities found within each habitat for each of the three installations (Table 10). Analysis of avian diversity indices among survey sites or days at Camp Florence and Fort Hood was not possible due to missing values and resulting redundancies in ANOVA design matrices. Data from

Fort Bliss could be examined by survey sites for data collected during 1993 and 1994, but similar problems to those found at the other installations precluded use of Fisher's α. Each of the remaining three diversity indices (S, d_s, H') produced consistently similar results in describing avian diversity at Fort Bliss (Figure 14). Power of diversity indices varied between years. During 1993, none of the three indices attained satisfactory power even with up to six survey sites, yet during 1994, all three indices yielded high power with three or more survey sites (Figure 14).

For small mammal communities, diversity indices were generated for both habitats at each of the three installations (Table 10). Statistical power associated with the analysis of small mammal diversity indices was low at all installations (Table 11).

Several general trends were evident when data from Camp Florence were examined by trap array types and diversity indices. When diversity indices were calculated for each sample, power was low and never reached satisfactory levels (Figure 15). When captures were pooled over nights, trapping methods yielded greater power (Figure 16). Observed differences were due more to sampling method than to index. However, power was still generally low for diversity indices calculated from data collected using the Sherman and pitfall trap array, and the Museum Special and rat trap array. Only the Sherman/rat trap array with diversity indices d_s, H', and Fisher's α, achieved adequate power (Figure 16). Both d_s and H' attained sufficient power at five nights. Whereas, Fisher's α attained sufficient power on the seventh night (Figure 16). The combination of trap array and diversity index that yielded the best power values was the Sherman/rat trap array and d_s (Figure 17). The low number of captures at Fort Hood precluded making these kinds of comparisons.

Table 3. Avian species observed during surveys on Camp Florence, AZ, 3 through 19 March 1993.

		Habitat		
Common Name	**Scientific Name**	**Cactus**	**Creosote**	**Total**
Cactus Wren	*Campylorhynchus brunneicapillus*	443	371	814
Curve-billed Thrasher	*Toxostoma curvirostris*	168	135	303
House Finch	*Carpodacus mexicanus*	170	123	293
Gila Woodpecker	*Melanerpes uropygiale*	185	101	286
Ash-throated Flycatcher	*Myiarchus cinerascens*	118	122	240
Verdin	*Auriparus flaviceps*	44	46	90
Black-tailed Gnatcatcher	*Polioptila melanura*	40	43	83
Gambel's Quail	*Callipepla gambelii*	45	31	76
Black-throated Sparrow	*Amphispiza bilineata*	43	21	64
Mourning Dove	*Zenaida macroura*	29	30	59
Northern Mockingbird	*Mimus polyglottos*	27	14	41
Phainopepla	*Phainopepla nitens*	23	10	33
Brown-headed Cowbird	*Molothrus ater*	19	11	30
Common Flicker	*Colaptes auratus*	16	13	29
Brown-crested Flycatcher	*Myiarchus tyrannulus*	20	7	27
Northern Cardinal	*Cardinalis cardinalis*	8	10	18
Red-tailed Hawk	*Buteo jamaicensis*	4	10	14
White-winged Dove	*Zenaida asiatica*	10	2	12
Bendire's Thrasher	*Toxostoma bendirei*	3	4	7
American Kestrel	*Falco sparverius*	0	5	5
Ladder-backed Woodpecker	*Picoides scalaris*	0	4	4
Northern Oriole	*Icterus galbula*	3	0	3
Brown Towhee	*Pipilo fuscus*	3	0	3
Olive-sided Flycatcher	*Contopus borealis*	2	0	2
Loggerhead Shrike	*Lanius ludovicianus*	0	2	2
European Starling	*Sturnus vulgaris*	0	2	2
Lucy's Warbler	*Vermivora luciae*	0	2	2
Wilson's Warbler	*Wilsonia pusilla*	0	2	2
Western Tanager	*Piranga ludoviciana*	1	0	1
Black-throated Gray Warbler	*Dendroica nigrescens*	0	1	1
Totals		1424	1122	2546

Table 4. Avian species observed during surveys on Fort Hood, TX, 17 June through 12 July 1993.

		Habitat		
Common Name	**Scientific Name**	**Savannah**	**Forest**	**Total**
Northern Cardinal	*Cardinalis cardinalis*	320	226	546
Northern Mockingbird	*Mimus polyglottos*	224	258	482
Mourning Dove	*Zenaida macroura*	116	182	298
Northern Bobwhite	*Colinus virginianus*	115	151	266
Carolina Wren	*Thryothorus ludovicianus*	109	138	247
Lark Sparrow	*Chondestes grammacus*	87	159	246
Brown-headed Cowbird	*Molothrus ater*	121	54	175
Yellow-billed Cuckoo	*Coccyzus americanus*	61	41	102
Tufted Titmouse	*Parus bicolor*	38	47	85
Blue-gray Gnatcatcher	*Polioptila caerulea*	16	54	70
Carolina Chickadee	*Parus carolinensis*	42	21	63
Eastern Meadowlark	*Sturnella magna*	41	22	63
Common Nighthawk	*Chordeiles minor*	31	27	58
Ruby-throated Hummingbird	*Archilochus colubris*	33	14	47
White-eyed Vireo	*Vireo griseus*	20	11	31
Chimney Swift	*Chaetura pelagica*	28	1	29
Painted Bunting	*Passerina ciris*	15	10	25
Turkey Vulture	*Cathartes aura*	16	3	19
Barn Swallow	*Hirundo rustica*	17	1	18
Cliff Swallow	*Hirundo pyrrhonota*	5	7	12
Ladder-backed Woodpecker	*Picoides scalaris*	7	0	7
Golden-cheeked Warbler	*Dendroica chrysoparia*	0	6	6
Black-capped Chickadee	*Parus atricapillus*	0	6	6
Scissor-tailed Flycatcher	*Tyrannus forficatus*	4	0	4
Red-tailed Hawk	*Buteo jamaicensis*	2	0	2
Great Blue Heron	*Ardea herodias*	1	1	2
Red-winged Blackbird	*Agelaius phoeniceus*	0	2	2
Red-bellied Woodpecker	*Melanerpes carolinus*	1	0	1
Killdeer	*Charadrius vociferus*	0	1	1
Totals		1470	1443	2913

Table 5. Avian species observed during surveys on Fort Bliss, TX, 5 May through 8 June 1993 and 3 through 23 May 1994.

		Habitat		
Common Name	**Scientific Name**	**Arroyo**	**Upland**	**Total**
Black-throated Sparrow	*Amphispiza bilineata*	166	162	328
Northern Mockingbird	*Mimus polyglottos*	137	19	156
Mourning Dove	*Zenaida macroura*	124	29	153
House Finch	*Carpodacus mexicanus*	93	14	107
Eastern Meadowlark	*Sturnella magna*	37	68	105
Western Kingbird	*Tyrannus verticalis*	66	14	80
Scott's Oriole	*Icterus parisorum*	60	14	74
Cassin's Sparrow	*Aimophila cassinii*	28	32	60
Brown-headed Cowbird	*Molothrus ater*	51	0	51
Ash-throated Flycatcher	*Myiarchus cinerascens*	42	2	44
Lark Bunting	*Calamospiza melanocorys*	40	4	44
Common Nighthawk	*Chordeiles minor*	11	23	34
Horned Lark	*Eremophila alpestris*	0	24	24
Brown Towhee	*Pipilo fuscus*	15	1	16
Scaled Quail	*Callipepla squamata*	15	0	15
Cactus Wren	*Campylorhynchus brunneicapillus*	12	1	13
Blue Grosbeak	*Guiraca caerulea*	12	0	12
Green-tailed Towhee	*Pipilo chlorurus*	12	0	12
Lark Sparrow	*Chondestes grammacus*	3	8	11
Loggerhead Shrike	*Lanius ludovicianus*	9	2	11
Cassin's Kingbird	*Tyrannus vociferans*	6	3	9
Crissal Thrasher	*Toxostoma dorsale*	8	0	8
Brewer's Sparrow	*Spizella breweri*	7	0	7
Wilson's Warbler	*Wilsonia pusilla*	7	0	7
Rufous-crowned Sparrow	*Aimophila ruficeps*	2	3	5
Broad-tailed Hummingbird	*Selasphorus platycercus*	1	3	4
Dusky Flycatcher	*Empidonax oberholseri*	4	0	4
Ladder-backed Woodpecker	*Picoides scalaris*	4	0	4
Virginia's Warbler	*Vermivora virginiae*	4	0	4
Violet-green Swallow	*Tachycineta thalassina*	3	0	3
Lesser Nighthawk	*Chordeiles acutipennis*	0	2	2
Western Tanager	*Piranga ludoviciana*	2	0	2
White-crowned Sparrow	*Zonotrichia leucophrys*	2	0	2
Barn Swallow	*Hirundo rustica*	1	0	1
Bell's Vireo	*Vireo bellii*	1	0	1
Curve-billed Thrasher	*Toxostoma curvirostre*	1	0	1
Gambel's Quail	*Callipepla gambelii*	1	0	1
Greater Roadrunner	*Geococcyx californianus*	1	0	1
Indigo Bunting	*Passerina cyanea*	1	0	1
MacGillivray's Warbler	*Oporornis tolmiei*	1	0	1
Red-tailed Hawk	*Buteo jamaicensis*	1	0	1
Ruby-crowned Kinglet	*Regulus calendula*	1	0	1
Sage Sparrow	*Amphispiza belli*	1	0	1
Say's Phoebe	*Sayornis saya*	1	0	1
Verdin	*Auriparus flaviceps*	1	0	1
Western Meadowlark	*Sturnella neglecta*	0	1	1
Western Wood-Pewee	*Contopus sordidulus*	1	0	1
Yellow Warbler	*Dendroica petechia*	1	0	1
Totals		997	429	1426

Table 6. Similarity index values from avian and small mammal surveys.

Index Value	Symbol	Camp Florence	Fort Hood	Fort Bliss
Birds				
Percent Similarity[a]	*PS*	78	84	27
Jaccard[b]	C_j	0.63	0.72	0.37
Sorenson quantatitive	C_N	0.88	0.99	0.60
Morisita-Horn	C_{MH}	0.99	0.93	0.67
Mammals				
Percent Similaritya	*PS*	90	50	100
Jaccard[b]	C_j	0.82	0.25	0.75
Sorenson quantatitive	C_N	0.88	0.94	0.78
Morisita-Horn	C_{MH}	0.29	0.29	0.49

[a]Values can range from 0 (complete dissimilarity) to 100 (complete similarity).
[b]Values can range from 0 (complete dissimilarity) to 1 (complete similarity).

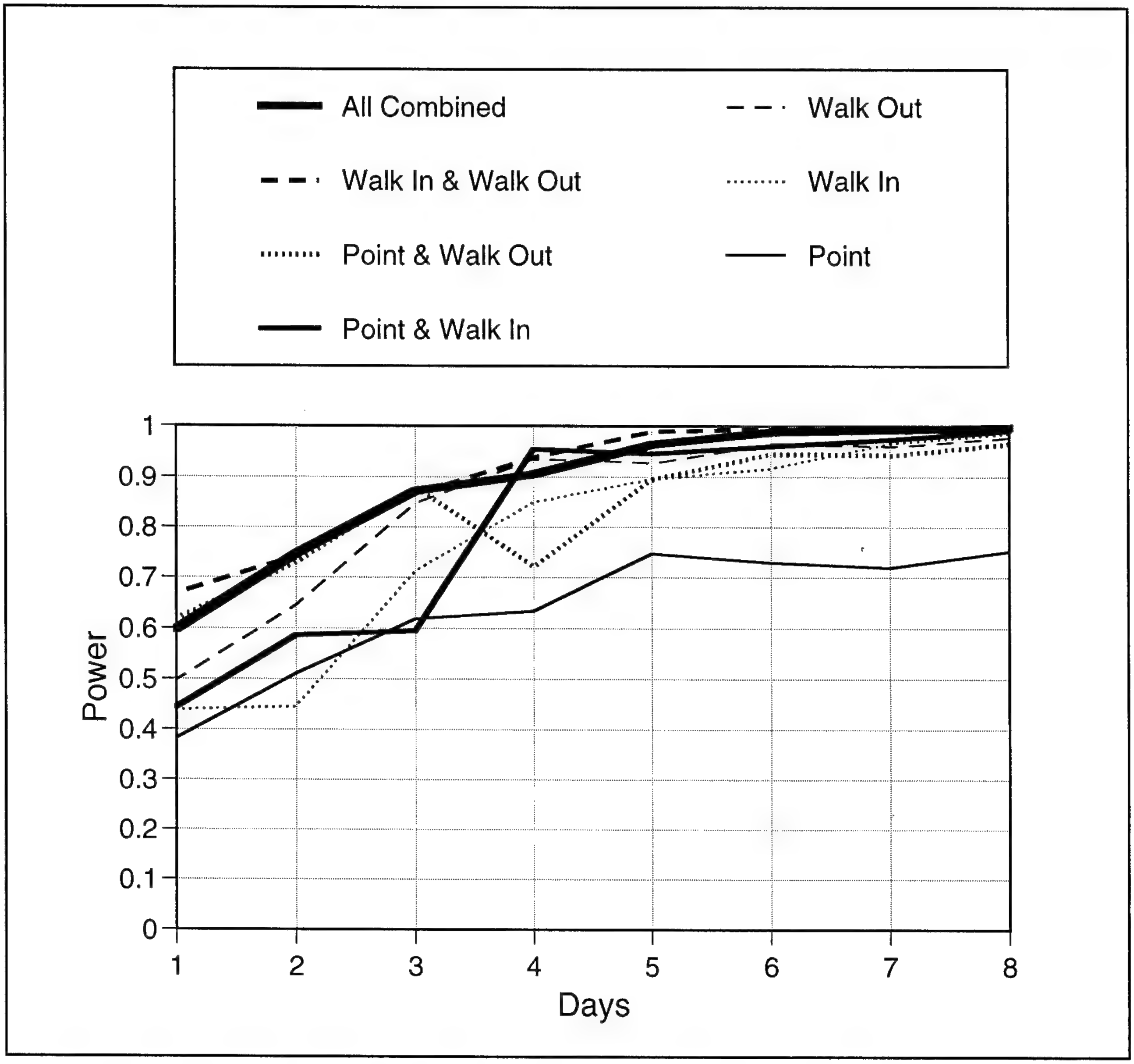


Figure 6. Power to detect differences in avian community composition at Camp Florence.

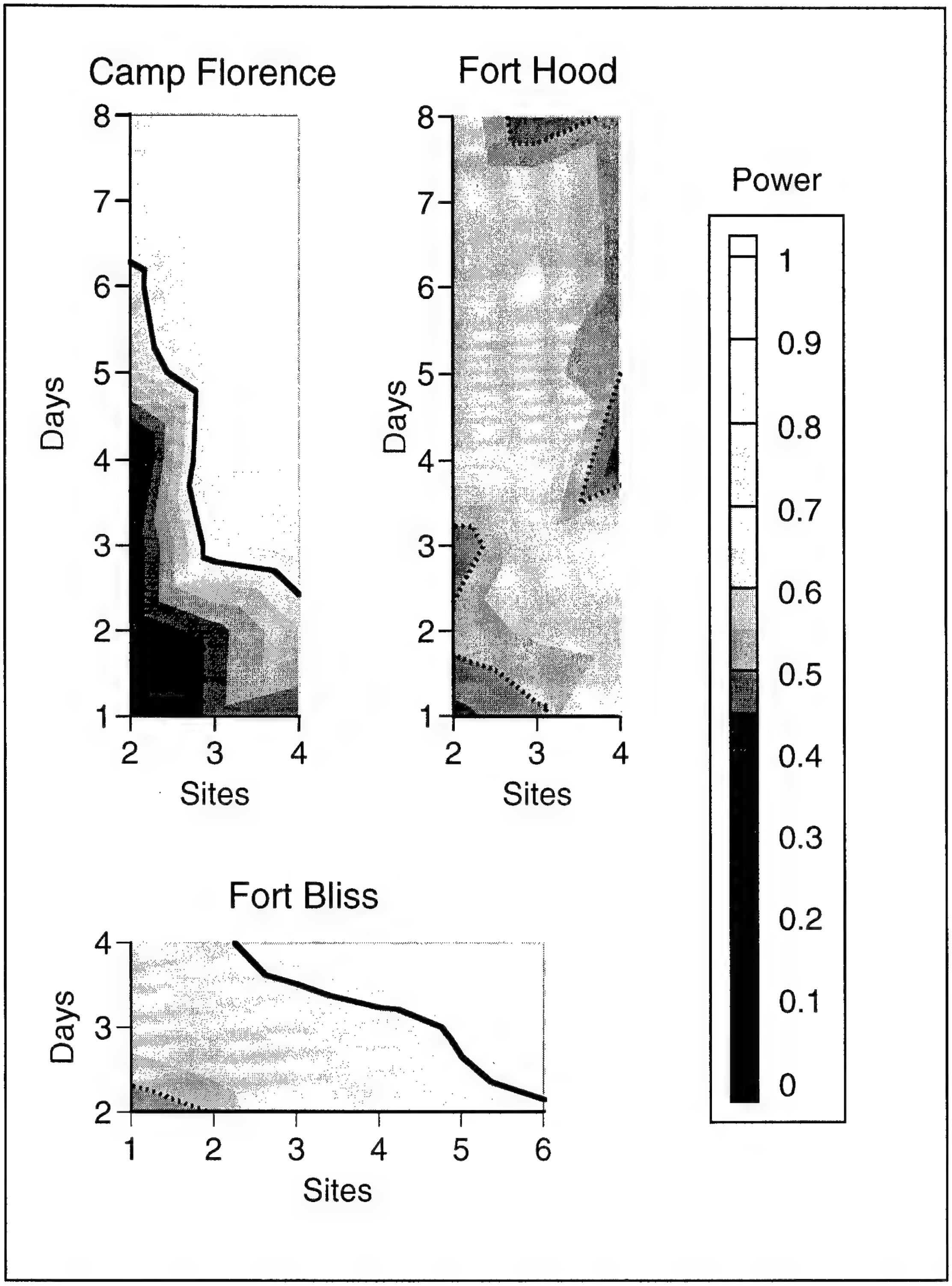


Figure 7. Power to detect differences in avian community composition at Camp Florence, Fort Hood, and Fort Bliss.

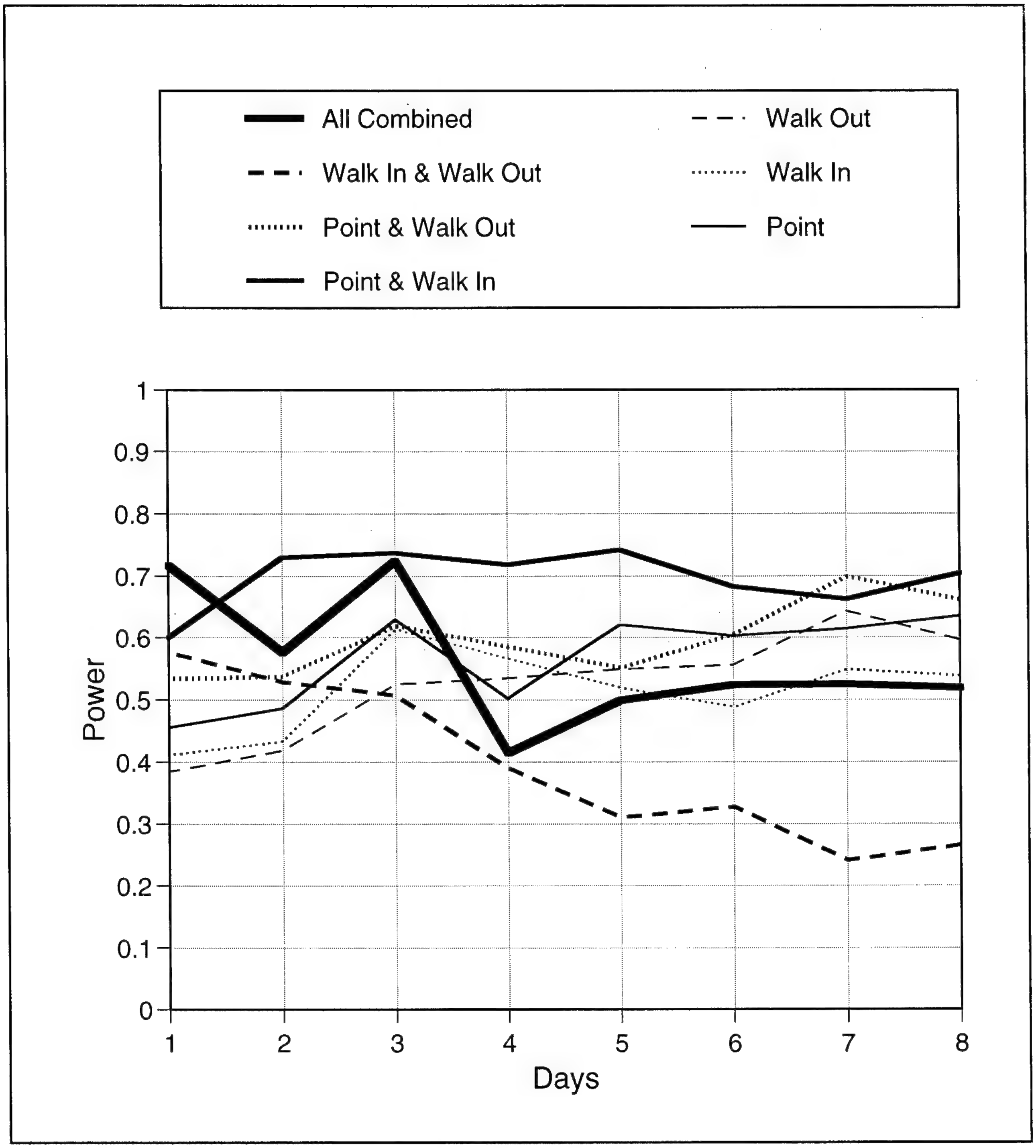


Figure 8. Power to detect differences in avian community composition at Fort Hood.

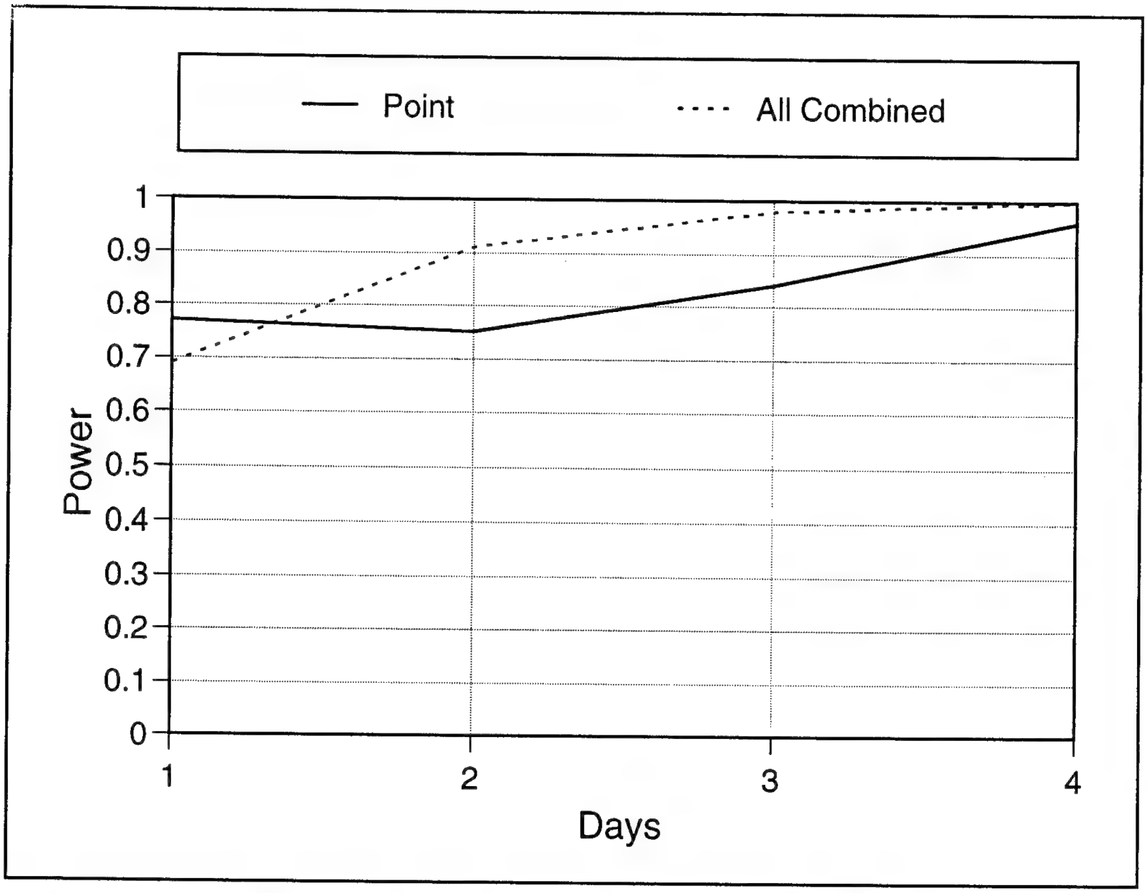


Figure 9. Power to detect differences in avian community composition at Fort Bliss.

Table 7. Mammal species captured during surveys on Camp Florence, AZ, 8 September through 15 October 1993.

		Habitat		
Common Name	**Scientific Name**	**Cactus**	**Creosote**	**Total**
Bailey's Pocket Mouse	*Perognathus baileyi*	185	16	201
Silky Pocket Mouse	*Perognathus flavus*	5	87	92
Desert Pocket Mouse	*Perognathus penicillatus*	51	28	79
Merriam Kangaroo Rat	*Dipodomys merriami*	25	51	76
Rock Pocket Mouse	*Perognathus intermedius*	27	13	40
Arizona Pocket Mouse	*Perognathus amplus*	4	33	37
Whitethroat Woodrat	*Neotoma albigula*	5	5	10
Bannertail Kangaroo Rat	*Dipodomys spectabilis*	0	5	5
Harris Antelope Squirrel	*Ammospermophilus harrisi*	2	2	4
Cactus Mouse	*Peromyscus eremicus*	1	1	2
Arizona Cotton Rat	*Sigmodon arizonae*	0	1	1
Totals		305	242	547

Table 8. Mammal species captured during surveys on Fort Hood, TX, 26 October through 3 December 1993.

		Habitat		
Common Name	**Scientific Name**	**Savannah**	**Forest**	**Total**
White-footed Mouse	*Peromyscus leucopus*	5	40	45
Texas Mouse	*Peromyscus atwatteri*	8	9	17
Hispid Cotton Rat	*Sigmodon hispidus*	16	0	16
Northern Pygmy Mouse	*Baiomys taylori*	7	4	11
Fulvous Harvest Mouse	*Reithrodontomys fulvescens*	7	0	7
Plains Harvest Mouse	*Reithrodontomys montanus*	4	0	4
Least Shrew	*Cryptotis parva*	2	0	2
Deer Mouse	*Peromyscus maniculatus*	0	2	2
Silky Pocket Mouse	*Perognathus flavus*	1	0	1
Hispid Pocket Mouse	*Perognathus hispidus*	1	0	1
Brush Mouse	*Peromyscus boylei*	0	1	1
Eastern Cottontail	*Sylvilagus floridanus*	0	1	1
Totals		51	57	108

Table 9. Mammal species captured during surveys on Fort Bliss, TX, 25 April through 20 May 1993.

		Habitat		
Common Name	**Scientific Name**	**Arroyo**	**Upland**	**Total**
White-footed Mouse	Peromyscus leucopus	84	59	143
Merriam Kangaroo Rat	Dipodomys merriami	15	118	133
Western harvest Mouse	Reithrodontomys megalotis	64	45	109
Ord Kangaroo rat	Dipodomys ordi	90	17	107
Plains Pocket Mouse	Perognathus flavescens	5	93	98
Cactus Mouse	Peromyscus eremicus	5	65	70
Deer Mouse	Peromyscus maniculatus	28	23	51
Whitethroat Woodrat	Neotoma albigula	6	38	44
Silky Pocket Mouse	Perognathus flavus	14	29	43
Hispid Pocket Mouse	Perognathus hispidus	9	18	27
Mearn's Grasshopper Mouse	Onychomys arenicola	3	13	16
Rock Pocket Mouse	Perognathus intermedius	5	6	11
Hispid Cotton Rat	Sigmodon hispidus	6	0	6
Southern Plains Woodrat	Neotoma micropus	5	0	5
Bannertail Kangaroo Rat	Dipodomys spectabilis	0	1	1
Northern Grasshopper Mouse	Onychomys leucogaster	0	1	1
Totals		339	526	865

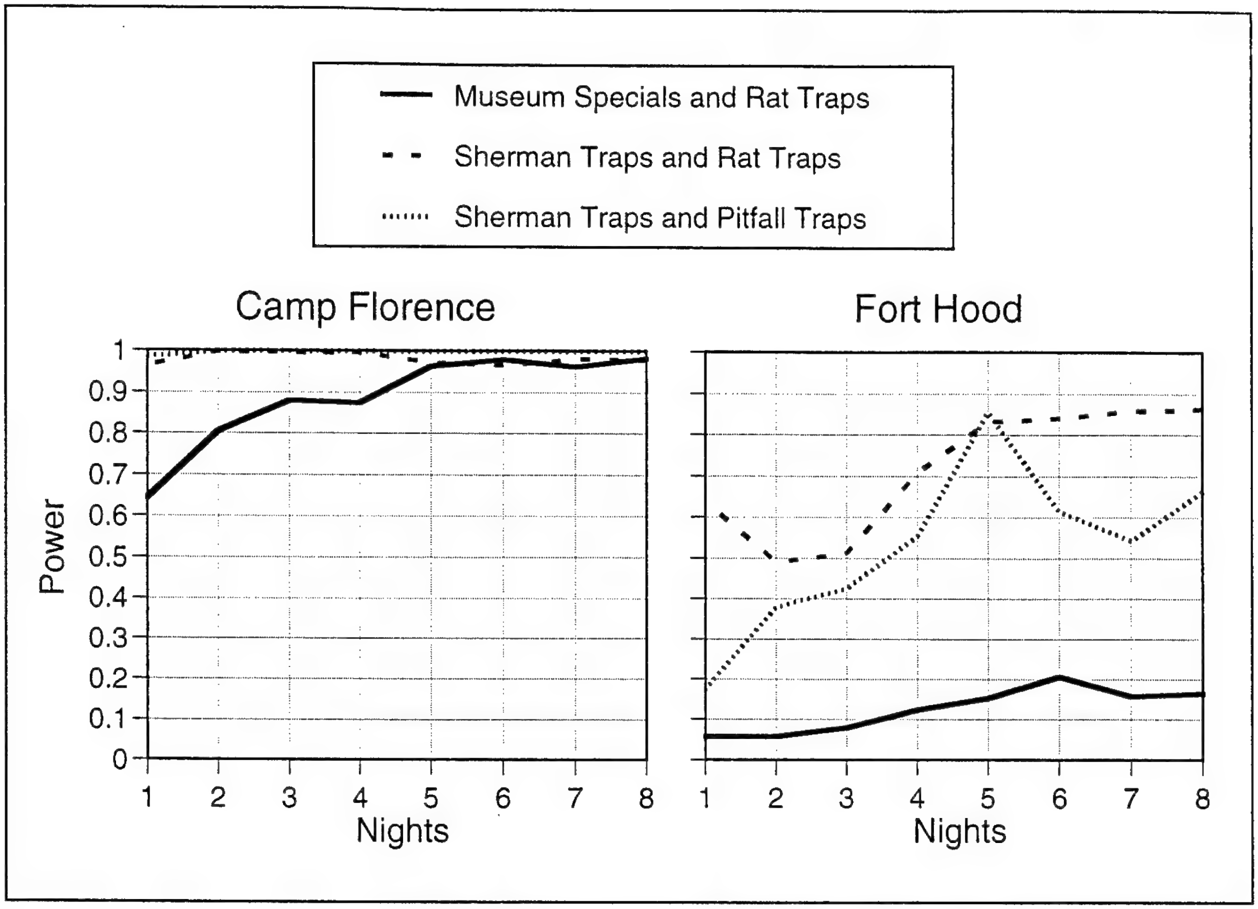


Figure 10. Power to detect differences in small mammal community composition at Camp Florence and Fort Hood.

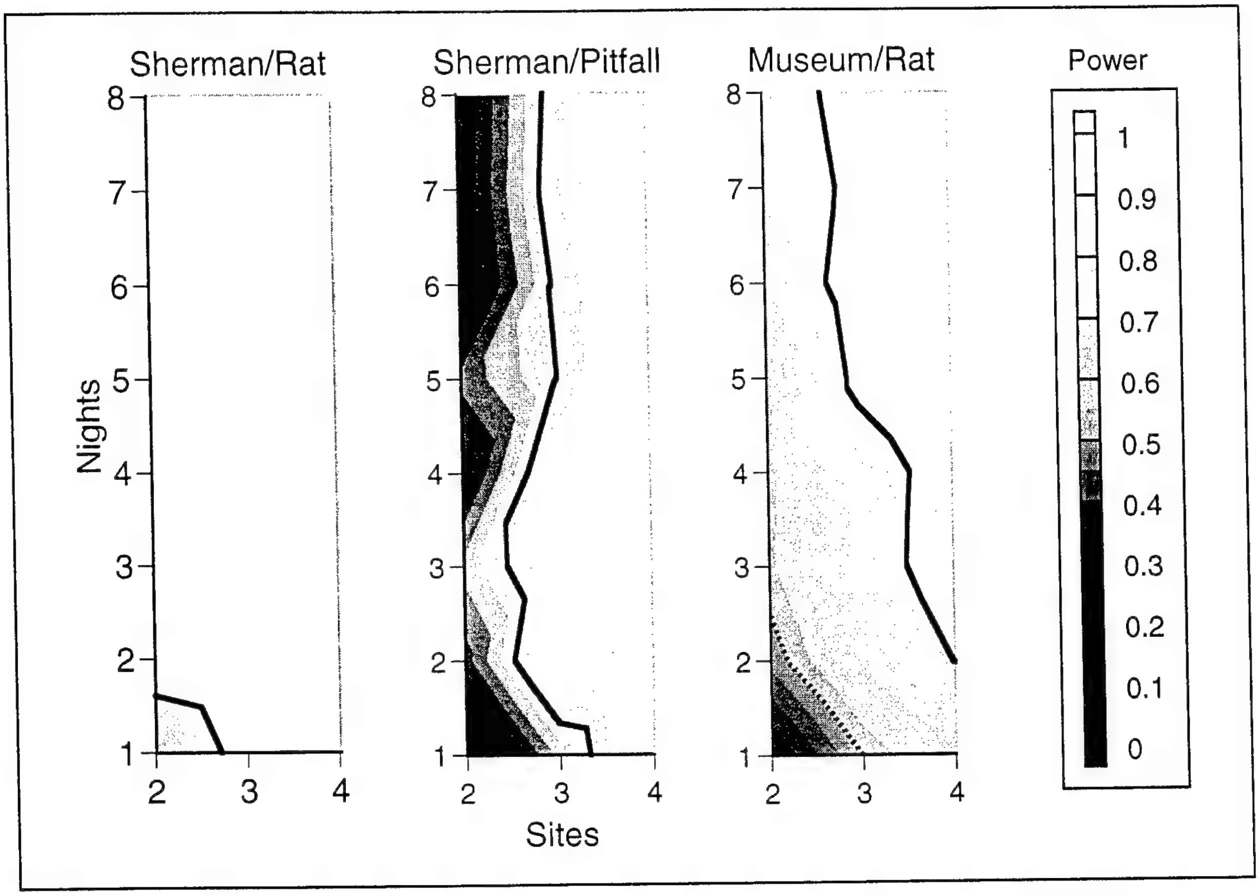


Figure 11. Power to detect differences in small mammal community composition at Camp Florence.

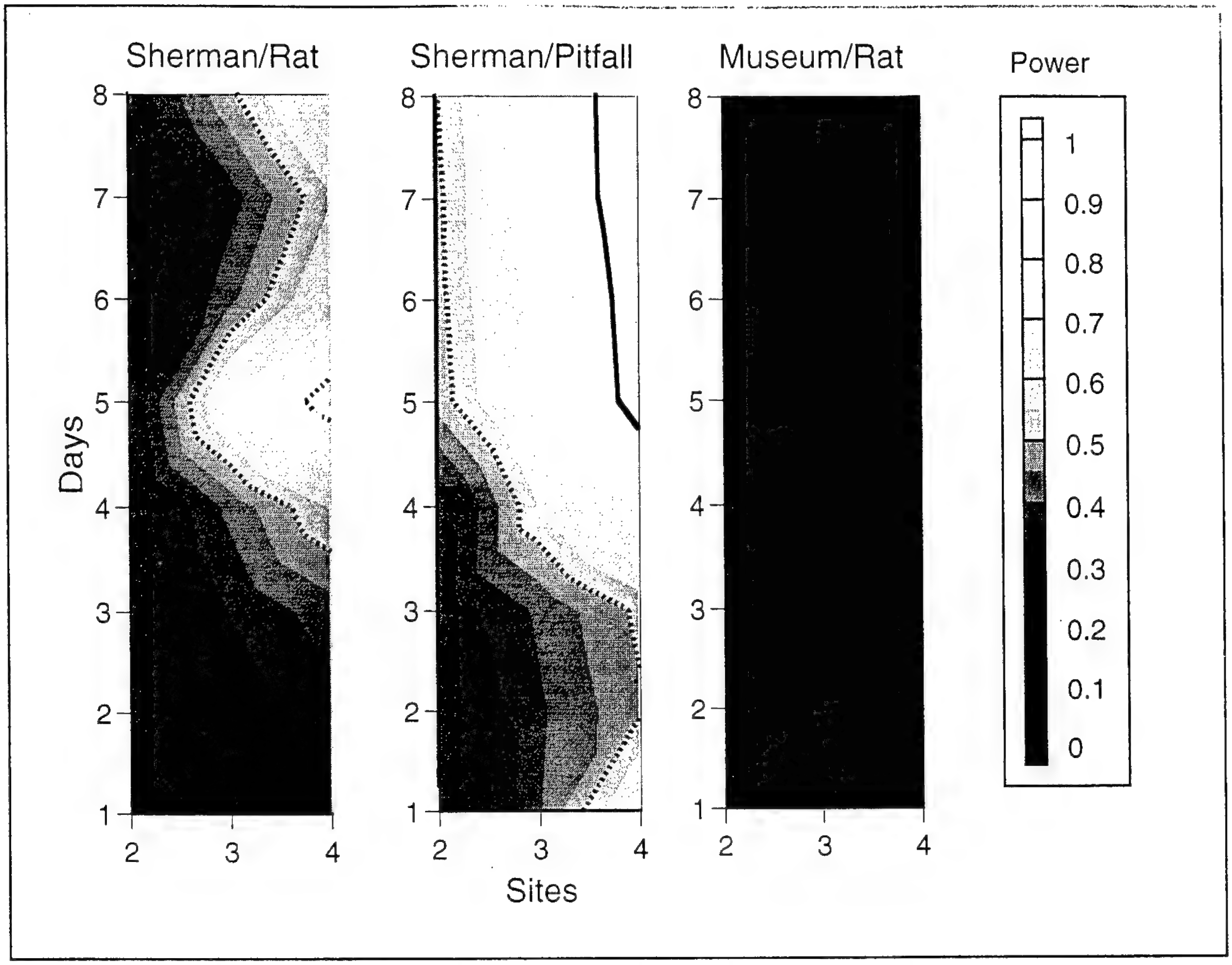


Figure 12. Power to detect differences in small mammal community composition at Fort Hood.

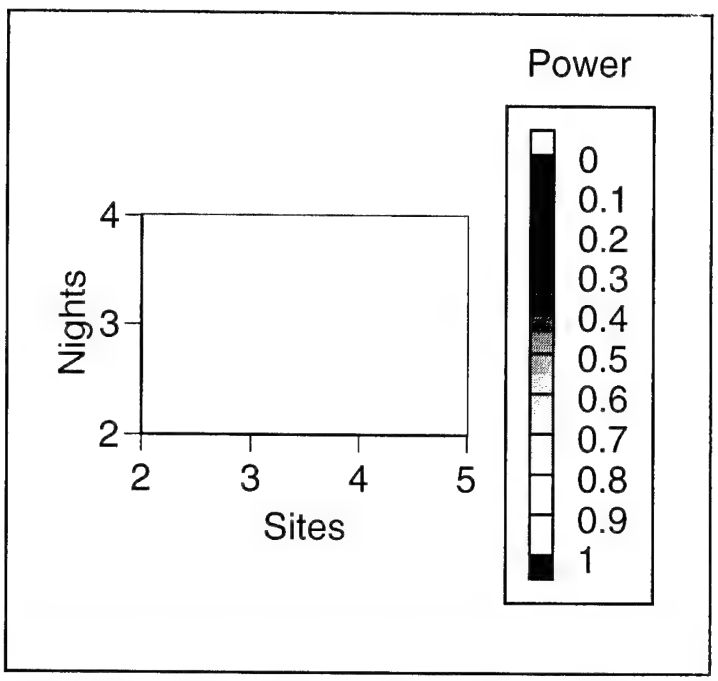


Figure 13. Power to detect differences in small mammal community composition at Fort Bliss.

Table 10. Diversity index values from pooled avian and small mammal data.

		Camp Florence		Fort Hood		Fort Bliss	
Index	**Symbol**	**Cactus**	**Creosote**	**Savannah**	**Forest**	**Arroyo**	**Upland**
Birds							
Number of Species	S	23	26	25	25	45	21
Reciprocal of Simpson's index	d_s	6.2	9.5	9.5	9.1	11.3	5.3
Shannon's Index	H'	2.3	2.3	2.6	2.5	2.8	2.2
Fisher's α	α	3.9	4.8	4.3	4.3	9.7	4.8
Mammals							
Number of Species	S	9	11	9	6	14	14
Reciprocal of Simpson's index	d_s	2.4	4.7	5.6	1.9	5.5	7.7
Shannon's Index	H'	1.3	1.8	1.9	1.0	2.0	2.2
Fisher's α	α	1.7	2.4	3.2	1.7	2.9	2.6

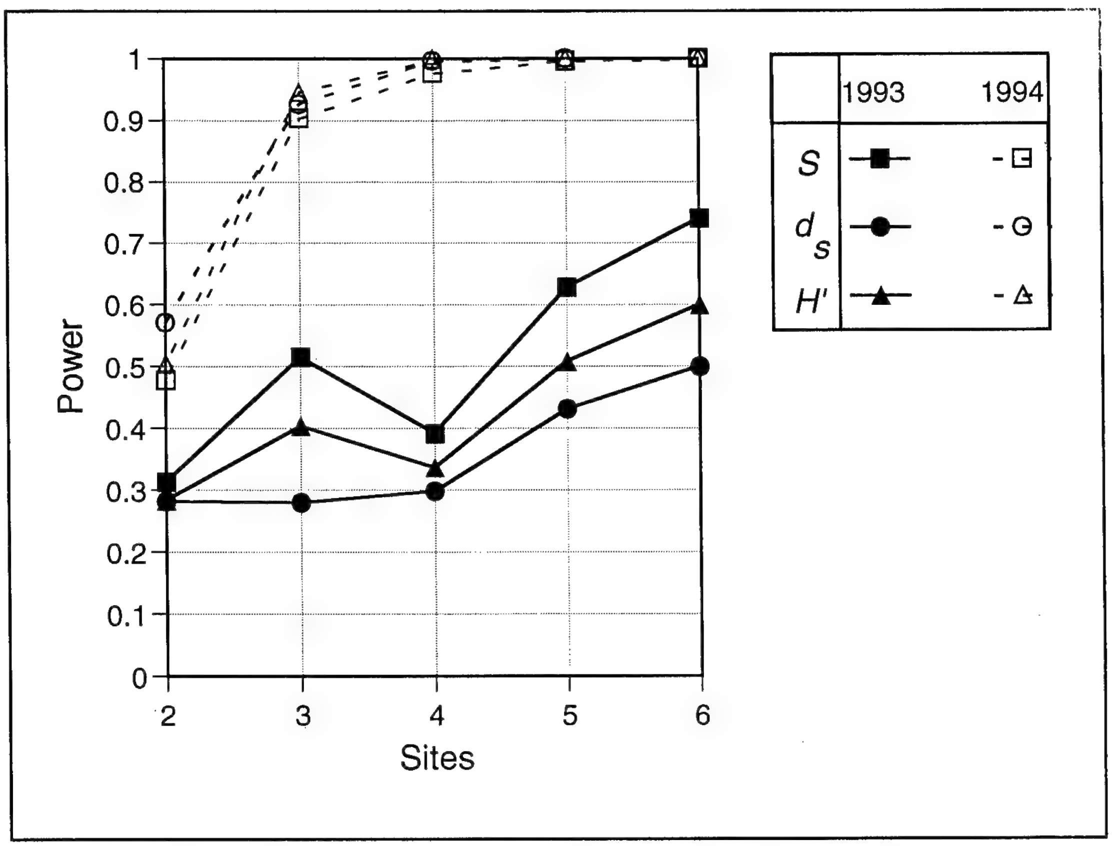


Figure 14. Power to detect differences in avian community diversity at Fort Bliss.

Table 11. Statistical power associated with diversity index values of small mammal captures.

		Camp Florence Sites			Fort Hood Sites			Fort Bliss Sites			
	Symbol	2	3	4	2	3	4	2	3	4	5
Number of Species	S	0.14	0.09	0.07	0.08	0.10	0.10	0.25	0.40	0.44	0.57
Reciprocal of Simpson's index	d_s	0.15	0.12	0.08	0.1	0.14	0.15	0.19	0.34	0.35	0.37
Shannon's Index	H'	0.15	0.13	0.09	0.16	0.13	0.12	0.24	0.31	0.35	0.37
Fisher's α	α	0.15	0.11	0.08	0.09	0.11	0.12				

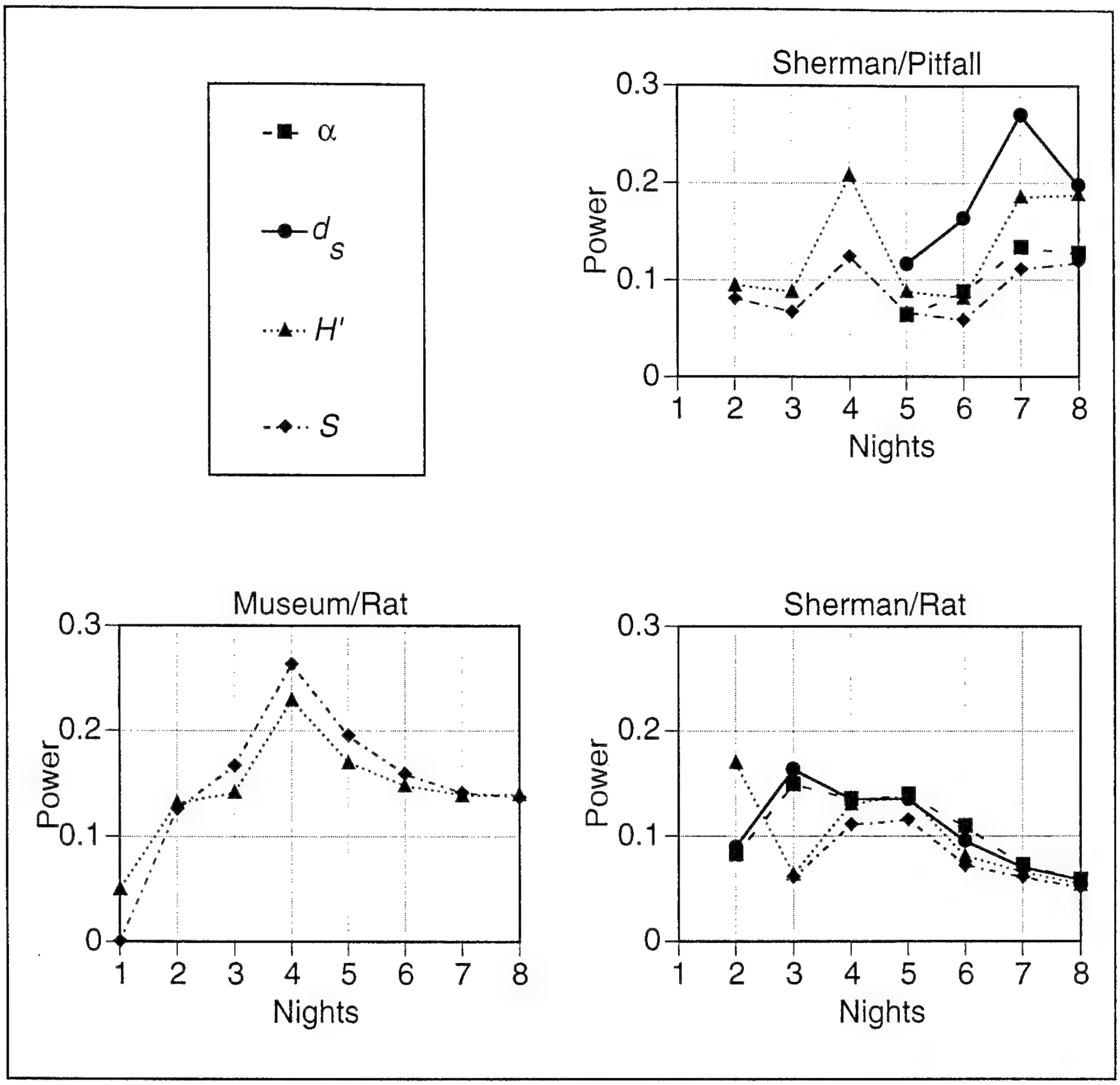


Figure 15. Power to detect differences in small mammal community diversity at Camp Florence (not pooled over days).

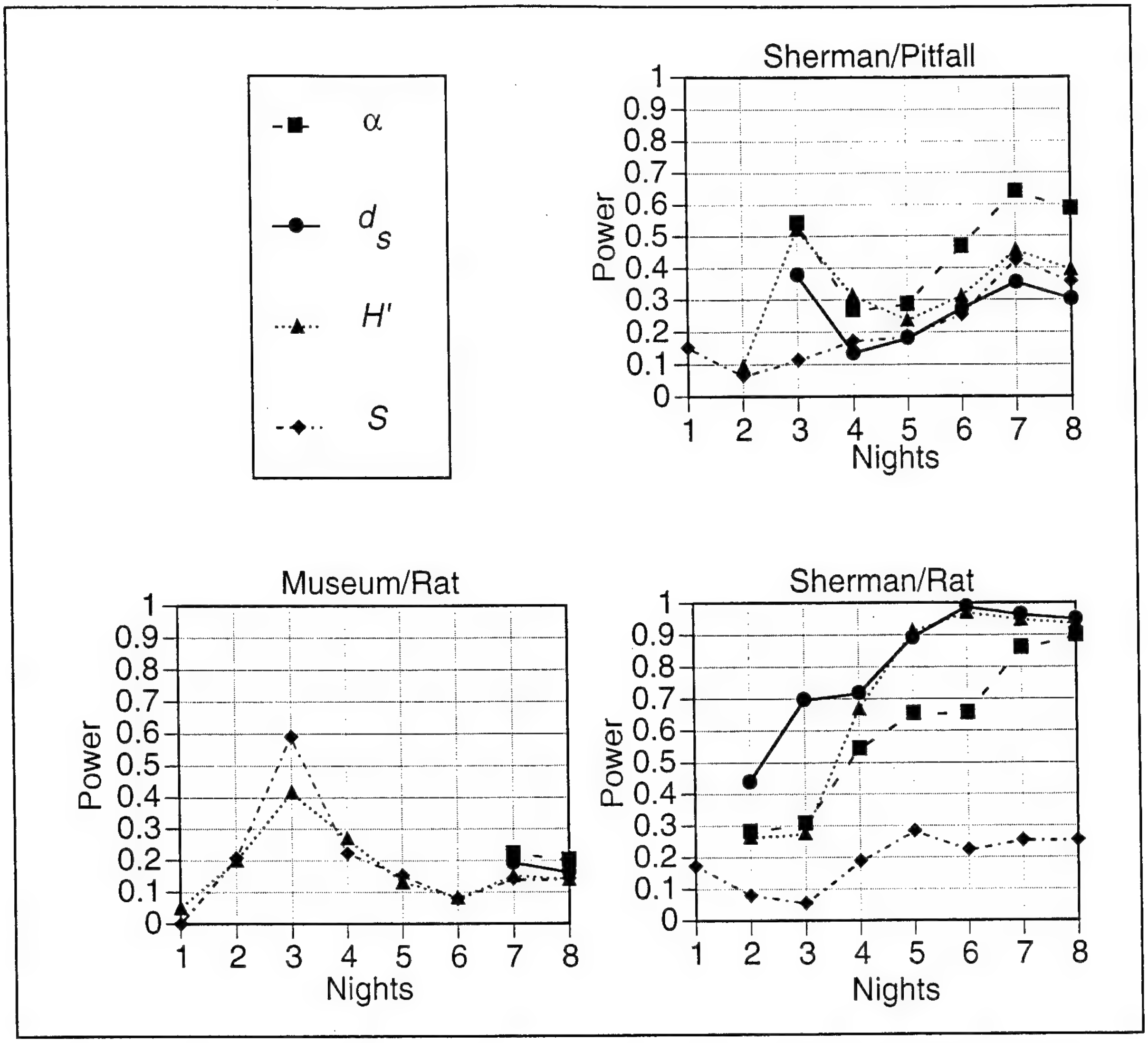


Figure 16. Power to detect differences in small mammal community diversity at Camp Florence (pooled over days).

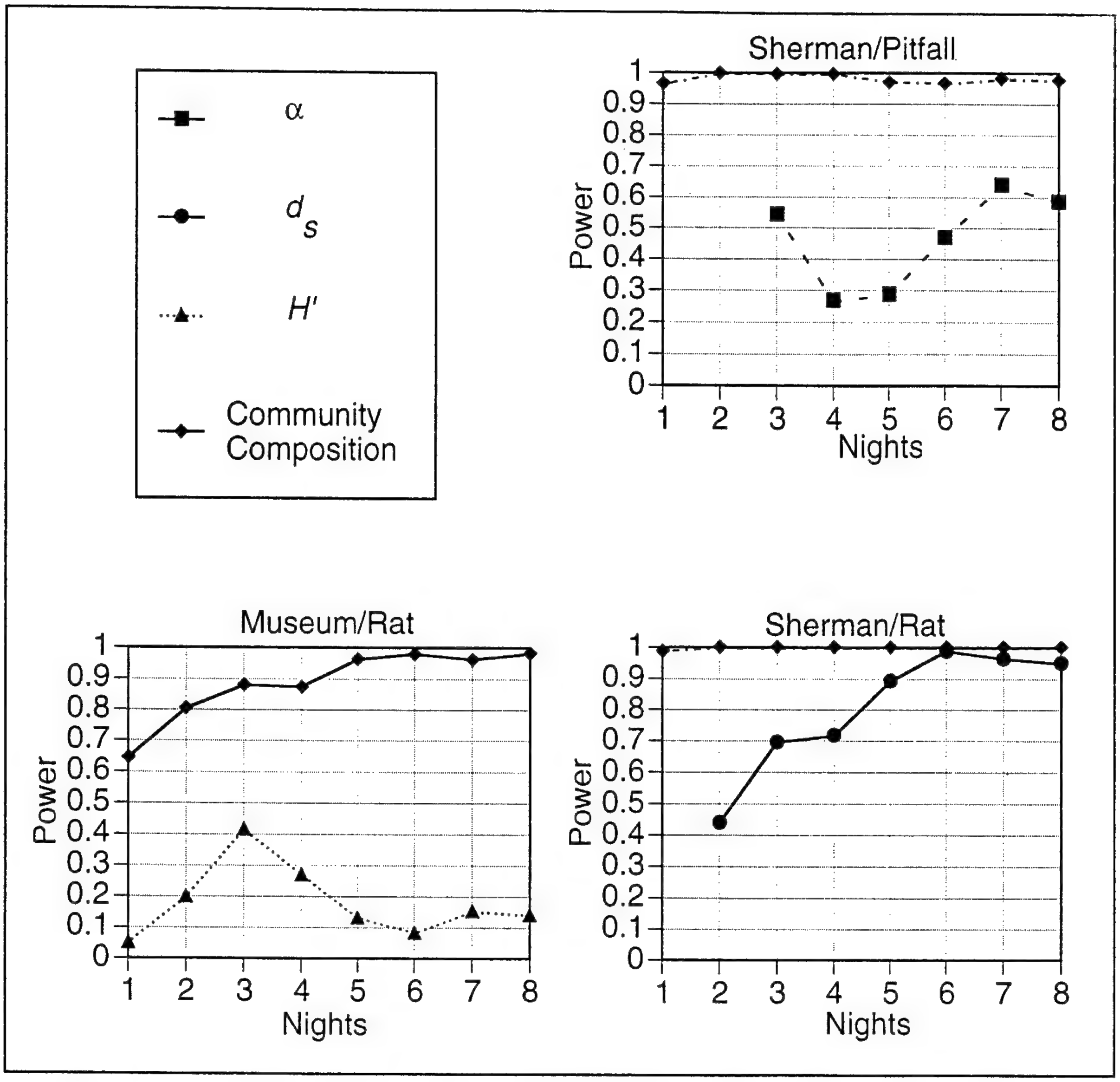


Figure 17. Comparison of power to detect differences in small mammal community diversity found in two habitats at Camp Florence using community composition and the best diversity index.

6 Discussion

Statistical power for main effects was consistently lower than that for the interaction. That is, species responses to habitat differences were more rapidly detected as changes in the relative abundance among species (changes in community composition) than changes in abundance for all species.

Avian Communities

At Camp Florence, the transect portions of the survey yielded more power than the point count. Point counts, in one form or another, are widely used in conducting bird surveys (Lancia, Nichols, and Pollock 1994) in forests or areas with rough terrain. Point counts allow the observer to concentrate on counting birds rather than simultaneously counting and negotiating difficult terrain features. Habitats on Camp Florence are fairly open desert scrub associations, which may allow easier detection of birds that are disturbed as a surveyor proceeds along the transect.

The behavior of desert birds may also contribute to higher power resulting from counts during the walking portion of the LCTA survey than during the point count survey. Temperatures often increase rapidly following sunrise and remain high throughout the day, thereby forcing birds to seek shade. Desert birds typically seek shade and remain relatively sedentary during the heat of the day to conserve water (Welty and Baptista 1988). Observers conducting transects would likely disturb birds that may not have been detected during point counts. Consequently, the effect of desert heat in influencing bird behavior should be considered when conducting surveys on installations in arid regions.

Given the higher power on transects at Camp Florence, it is not clear why power for the walking out portion of the bird surveys was higher than for the walking in portion. These two surveys covered the same ground in opposite directions. This means that for the walk out, the transect had been recently disturbed (during the walk in), but why this might yield higher power is uncertain.

Small Mammal Communities

In this study, arrays incorporating Sherman live traps yielded more power than arrays containing Museum Special snap traps, which are currently specified for LCTA small mammal trapping. The use of pitfall traps did not appreciably improve power so the use of this labor intensive method was not supported.

Diversity Indices

Diversity indices are a convenient means of summarizing community structure with a single number. Statistical power associated with analysis of diversity indices was substantially lower than comparisons involving community composition. This may be related to the reductionist characteristic of diversity indices, which reflect only certain types of community differences. Frequently, it was not possible to calculate (and consequently analyze) some of the diversity indices due to computational limitations. For example, it was not possible to calculate d_s when $\sum n_i(n_i - 1) = 0$ or Fisher's α when $N = S$. This occurred when low numbers of individuals of only a few species were found. As a result of incalculable index values, it often was not feasible to compare indices using ANOVA.

Effect Size

This analysis used the effect size exhibited by the data sets from each test to evaluate power. As a result, lack of power did not necessarily mean the methods were inadequate, but simply that the effect size was small. Without specifying a particular effect size, the appropriate use of this analysis is to compare one field technique or analytical approach with others using the same data set. For example, the fact that power was high for all types of mammal trapping arrays at Camp Florence, but smaller for all trap array types at Fort Hood, does not mean that mammal trapping worked better at Camp Florence. It may mean only that community differences were of a different magnitude at the two installations. The appropriate comparison is within each installation; which technique or approach yielded the higher power. It is then of interest to see if such comparisons show a consistent pattern or not.

Direct comparisons between installations would require that a standard effect size be applied to the analysis. Determining which effect size to use is a relatively easy judgment to make for main effects, but this analysis focused in the interaction effect (species by habitat). Judging what level of community change it is desirable to detect

is much more difficult. There are two possible approaches for making this judgment. The first is to use the similarity indices to assess the magnitude of the differences between the communities to evaluate power. The second is to assess the interaction effects of a number of other studies (such as environmental impact studies), and classify them subjectively according to degree of community difference and then use this classification as a standard for evaluating power. Both of these approaches are possible extensions of this research effort.

Sample Design

There was no consistent indication that power increased more with either increasing sampling sites or sampling days, but it appeared that increasing the number of sites was more important at Camp Florence, whereas the opposite was true at Fort Bliss (Table 12).

Table 12. Relative increase in power by increasing sampling by number of sites or number of days (or nights).

		Mammals		
	Birds	Sherman/Rat	Sherman/Pitfall	Museum/Rat
Camp Florence	Equal	Equal	Sites	Sites
Fort Hood	NA	NA	Equal	NA
Fort Bliss	Days	Nights	-	-

"-" indicates no sample.
"NA" indicates an assessment could not be made because of high variation in the power estimates.

7 Conclusions and Recommendations

Statistical power is an appropriate measure of the effectiveness of monitoring methods, since it is based on statistical procedures used in the evaluation.

For surveying birds in desert habitats, walking transects appear to be more effective than point counts. This is probably related to the habitat structure and behavior of the birds.

For small mammals, the power of community comparisons was lower using Museum Special snap traps, compared with arrays using Sherman live traps. The reason for this was not evident.

Although diversity indices provide important information on community structure, they were relatively unsuitable for reliably detecting differences between communities. Low power values and the high frequency of incalculable index values made community comparisons between habitats statistically of little use. A lack of detectable differences between communities may have been because the communities are similar, or because the communities have similar structure but differing composition.

Nationwide standard methods of monitoring Army lands are likely to result in variable efficiency and effectiveness among locations. Therefore, the minimum necessary degree of standardization should be identified and incorporated into the sampling regime, while still allowing for the maximum amount of adaptation of protocols for specific ecosystems. It may be preferable to specify inventory and monitoring standards that need to be achieved, as opposed to specifying particular methods and designs.

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